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Distribution and Diversity of Ant Genera from Selected Ecoregions across Nebraska

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ABSTRACT We documented distribution and diversity of ant genera in four of the six level III ecoregions across Nebraska. We sampled ants using bait cards, pitfall traps, and by opportunistic sampling, including direct collection and in carrion-baited pitfall traps. We identified 22 genera from five subfamilies, which were further classified into six functional groups. In common with other Great Plains states, *Formica* Linnaeus and *Lasius* Fabricius occurred most frequently in our samples, and overall ant genus-level richness was comparable to surrounding states. We compared genera similarity using Jaccard's similarity index within and between the High Plains (western-most) and Western Corn Belt Plains (eastern-most) ecoregions. We found higher mean similarity index values within the ecoregions than between the two ecoregions. Comparisons of ant genera and functional groups indicate similar patterns in estimating diversity and identifying assemblage differences across habitats. Taxonomic sufficiency is less when using functional group rather than ant genus because identification to subgenus is needed for some functional group designations. Our study provides baseline information useful for developing protocols for monitoring or assessing habitat changes and contributes the first list of ant genera across the state of Nebraska.

KEYWORDS ants, diversity, ecoregions, Formicidae, functional group, Great Plains, Nebraska

Grassland ecosystems have become rare in the 20th century because of urban expansion, agricultural conversion, invasion of exotic flora and fauna, fire suppression, artificial soil stabilization, and natural succession (Steinauer and Bragg 1987, Samson and Knopf 1994, Sieg et al. 1999, Briggs et al. 2005, Clark and Tilman 2008). Although these transformations are physically apparent, documenting changes in animal diversity in these complex terrestrial ecosystems remains difficult. Often target taxa are chosen as biological indicators to monitor change; however, debate remains as to which species and even which level of taxonomy is necessary to assess change.

In general, bioindicator taxa are used for two major purposes: to estimate the current biodiversity of a habitat and potentially distinguish diversity levels between or among habitat types or to measure the change in diversity of a habitat with respect to pollution impacts, invasive species occurrence, land use, and climate change (McGoech 1998). Within a single taxon, there are still multiple levels of taxonomic resolution, which allows taxonomic sufficiency. Taxonomic sufficiency is a pragmatic approach that promotes identification to the coarsest resolution needed to achieve practical objectives (Pik et al. 2002). For example, assessment protocols have been developed to assess changes in arthropod assemblages utilizing order level identification, such as to evaluate orchard management practices (Ruano et al. 2004). Similarly, significant differences among insect families were documented by Hoback et al. (1999) for a Nebraska salt marsh and Riggins et al. (2009) documented differences among invertebrate families and genera in response to restoration of wet meadows. Rosser and Eggleton (2011) found that Coleopteran genera could serve as adequate surrogates for species richness in both tropical and temperate habitats.

Because insects are the most numerous and diverse organisms on Earth and because much of their biodiversity remains undescribed, basic inventories of occurrence for states, regions, and countries have not yet been developed for many important insect groups. This severely limits the use of potentially important biological indicator species for assessment of ecosystem changes. Moreover, because many insects are highly mobile, their presence in an ecosystem may be temporary, thus reducing the ability of biological monitoring to detect changes. Stephens and Wagner (2006) suggested that comprehensive invertebrate surveys can be less indicative of the true inhabitants of the ecosystem because many are transient visitors. Being less transient, many researchers have turned to using ants (Hymenoptera: Formicidae) and ant functional groups as bioindicators (Andersen 1997, Stephens and Wagner 2006, Underwood and Fisher 2006, Majer et al. 2007, Fagan et al. 2010, Gómez and Abril 2011).

Measurement of a bioindicator taxon's diversity should ideally provide similar results concerning the overall diversity of organisms found within a given habitat. This expectation is derived from specific characteristics of the bioindicator taxon, which includes their ecosystem roles and sensitivities to change (Folgarait 1998, Agosti 2000). In this regard, the stationary, perennial nests of ants provide opportunities to gather data with resampling and for doing long-term inventories (Folgarait 1998), which are needed characteristics to assess or monitor the changes in

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ecosystems, including grasslands, from both loss and restoration or preservation practices. In addition, removal of ants from a colony, even through intensive sampling, is unlikely to cause negative impacts on the longevity and survival of a colony, making this a more desirable choice than sampling many other adult arthropods (Stephens and Wagner 2006).

Ants also function at many levels in an ecosystem, including as predators, prey, mutualists (Spomer and Hoback 1998), and herbivores (Hölldobler and Wilson 1990). Ant diversity is associated with structural habitat diversity (Fisher and Robertson 2002, Hill et al. 2008), plant diversity (Andersen 1995, Blüthgen et al. 2000, Boulton et al. 2005), land use (Bestelmeyer and Wiens 1996, Boulton et al. 2005), and soil type or structure (Folgarait 1998, Lobry de Bruyn 1999). Ant nesting habits facilitate the mixing of organic matter in the soil and improve soil aeration (Lobry de Bruyn 1999, Agosti 2000), thus impacting the overall health of a habitat, the assemblage of other invertebrates and plants, and indirectly humans (Folgarait 1998).

In some habitats, the distinction between species may not be as indicative of ecological changes as their functional roles are and thus, ant functional groups have been found to provide an adequate representation of changes across trophic levels, and to indicate disturbances in food chains (Folgarait 1998, King et al. 1998, Andersen et al. 2002, 2004, Yates and Andrew 2010). In Australia, functional groups have been used to measure the effects of restoration after mining, conservation of rare habitats, grazing on rangelands, and other disturbances (Andersen et al. 2004). Other studies which have used ants as bioindicators include assessment of pesticide impacts on invertebrates of banana plantations in Costa Rica (Matlock and De La Cruz 2003) and invasive species impacts on arthropod diversity in Florida (Morrison and Porter 2003).

The use of ant genus richness and composition to assess habitat conditions, and to monitor restoration efforts, is potentially important in grassland ecosystems of the Great Plains. However, baseline knowledge is necessary for a bioindicator to be successful, because it provides an assumption of normalcy even when an ecosystem is thought to be in various stages of recovery or degradation (Agosti 2000). Historically, ants in Nebraska have been incompletely studied and there are no comprehensive taxonomic lists. To our knowledge, Bare (1929) and Schmitt (1973) are the only published studies to inventory ant diversity in Nebraska. Thus, the objectives of this pilot study were to provide recent data on Nebraska's ant genera and to examine the taxonomic sufficiency of ant genus richness and ant functional groups in detecting habitat heterogeneity within and across the state's Level III ecoregions (Omernik 1987, Chapman et al. 2001, US EPA 2003).

STUDY AREA

The state of Nebraska is located in the central, continental United States and covers an area of 200,357 km^2. Elevation gradually increased, while annual precipitation gradually decreased, across the state from east to west (OSU 2000). Temperate climate was characterized by hot summers (mean 24° C), cold winters (mean −5° C), and markedly seasonal or periodic precipitation (i.e., 75% occurs between April and September; Harvey and Welker 2000). Habitats in Nebraska are part of a transitional region of North America's temperate grasslands historically dominated by tallgrass, mixed-grass, short-grass, and Sandhills prairies (Küchler 1964) with deciduous and coniferous forest primarily located along river systems (Weaver 1965). Many of these habitats were altered by agricultural development, tree planting, and woody plant encroachment (Steinauer and Bragg 1987, Sieg et al. 1999, Briggs et al. 2005). The estimated percent of remaining natural vegetation within Nebraska varied from less than 20% in the eastern quarter of the state to more than 80% in the Sandhills (Sieg et al. 1999). Nebraska is divided into six Level III ecoregions: Central Great Plains, High Plains, Nebraska Sandhills, Northwestern Glaciated Plains, Northwestern Great Plains, and Western Corn Belt Plains (Omernik 1987, Chapman et al. 2001, US EPA 2003). Eastern Nebraska's remaining tallgrass prairie, deciduous forest, and agricultural crops are grouped into the Western Corn Belt Plains ecoregion. Central mixed-grass prairie regions and agriculture dominate the Central Great Plains. The High Plains of western Nebraska consists of coniferous forest in elevated areas interspersed with short-grass prairies that are primarily used for grazing of cattle (Weaver 1965). The Sandhills region covers almost two-thirds of Nebraska and stretches into South Dakota (Küchler 1964). It is one of the largest grass-stabilized dune regions in the world (Bleed and Flowerday 1989). This region has not been successfully exploited for crops (Sieg et al. 1999) because of the sandy composition of the soil and lack of consistent moisture, but is used for rangeland cattle grazing.

Our survey sites were located across the state with a majority of locations in four of the six Level III ecoregions: High Plains, Central Great Plains, Sandhills, and Western Corn Belt Plains (Fig. 1). We collected samples between 24 May and 31 July 2004. Most sampling areas were State Wildlife Management Areas (SWMA) or other state owned areas, with the exception of a few privately owned lands for which permission was obtained.

METHODS

At each sampling location, we recorded the Global Positioning System (GPS) location for each sample and we described the microhabitat within an approximately 25-m radius as sandy, grass, woodland, or mixed (e.g., grass and woody vegetation). We used three common sampling

methods to collect ants, including opportunistic sampling, bait cards, and pitfall traps (Oliver and Beattie 1996, Folgarait 1998, Agosti 2000, King and Porter 2005, Underwood and Fisher 2006); we preserved ant specimens in 70% ethyl alcohol. Opportunistic collections consisted of manually retrieving ants from plants, the ground, carrion pitfall traps, or elsewhere with featherweight forceps or a manual aspirator. We performed this collection method as time permitted at sites. Bait cards consisted of using approximately 20 grams of tuna on each white plywood board (15 cm × 23 cm × 0.3 cm). We randomly placed four to ten bait cards on the ground or in vegetation at least 2 m apart within a habitat type for 30 to 60 minutes at 65 survey locations. After this time, we aspirated all ants on each card. Pitfall trap grids consisted of a 2 by 2 m area, in which 9 plastic vials (2 cm diameter and 10 cm deep) were spaced one meter apart in a grid pattern. We set vials into the ground so that the lip was flush with the ground. We placed soapy water into each vial to reduce viscosity and serve as a preservation solution. We collected specimens from vials each morning for one to three trap nights. One grid collection from one night of sampling was equivalent to one trap night. We used pitfall trap grids that were placed at least 25 m apart at 22 survey areas.

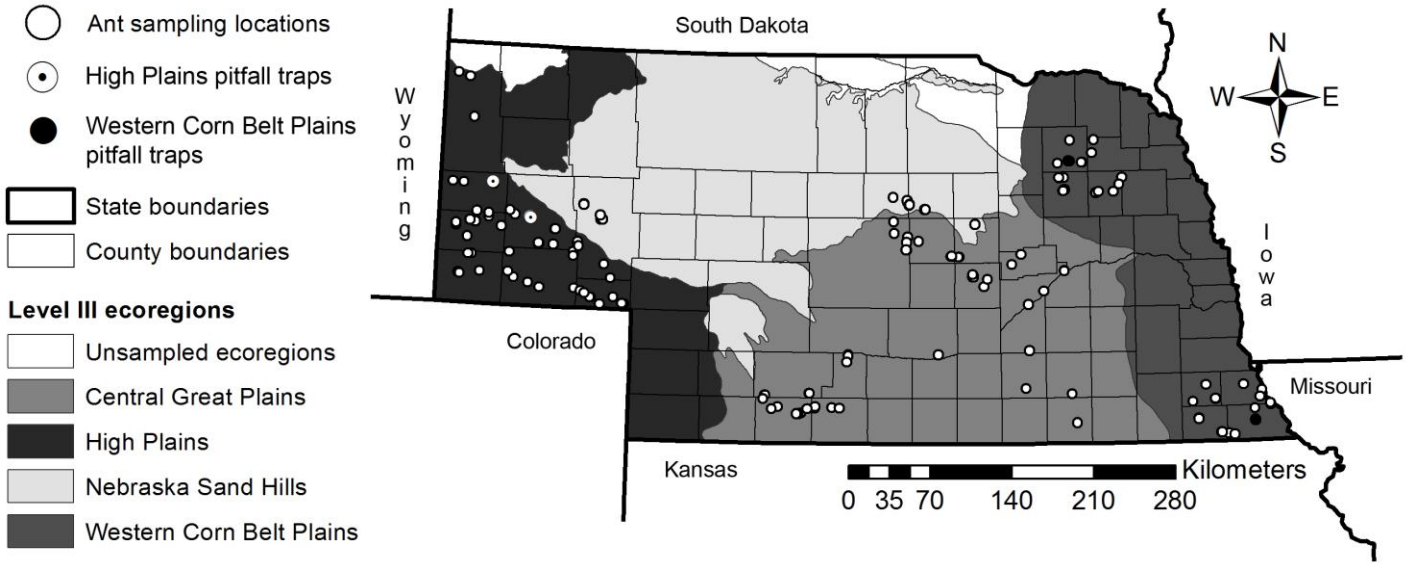

Figure 1. Ant survey locations, four pitfall trap locations used in Jaccard's analysis, and the level III ecoregions sampled in Nebraska during 2004.

Identification

We identified all ants to genus using keys in Creighton (1950), Hölldobler and Wilson (1990), Bolton (1994, 1995), Bolton et al. (2006), and Fisher and Cover (2007). We further identified *Formica* Linnaeus and *Lasius* Fabricius to group for use in functional group designations using a modified version of Andersen's (1995 and 1997) classifications, which are based on overall behavior and interactions of the genera. We assigned each genus or genus group to one of six functional groups: cryptic species, dominants, generalists, hot climate specialists, opportunists, and specialist predators. We modified functional group designations to account for behavioral differences in temperate, North American ant fauna. Major changes include the inclusion of *Forelius* Emery, *Lasius* (Niger group), *Prenolepis* Mayr, and *Solenopsis* (Diplorhopthrum subgenus) Westwood in the Generalists group because of their mass recruitment behavior. Genera with more inconspicuous recruitment placed within the Opportunists group were *Formica* (Microgyna group), *Lasius* (Umbratus group), *Myrmecina* Curtis, *Nylanderia* Emery, *Stenamma* Westwood, and *Temnothorax* Mayr. We placed reference and voucher specimens within the Biology Department Collection at the University of Nebraska at Kearney.

Diversity Measures and Data Analysis

We defined a sample as a single bait card collection, an entire pitfall trap array over the entirety of its sampling (e.g., one to three trap nights), or a single opportunistic sampling event. Despite this definition, pitfall collection samples were inherently more likely to contain more than one genus; whereas, the other methods were more likely to contain a single genus. Therefore, different methods were not considered equal in their ability to capture different ants per sample, but a distinction was needed to calculate occurrence. We calculated the number of samples in which each genus or genus group occurred for each sampling method and ecoregion. We created a list of ant genera

found in North America and surrounding Midwest states that was used to compare the ant genus richness of our dataset to surrounding areas.

We created a rank occurrence plot to depict ant genus richness in Nebraska and the four ecoregions sampled (SigmaPlot, Systat Software, Inc., Chicago, IL, USA). We constructed the rank occurrence plot by ranking the genus that occurred in the most samples as number one and then remaining genera were successively ranked with increasing numbers as their occurrence in samples decreased. We measured ant diversity by two components of the curve: the total length of the curve (i.e., the number of genera in the sample) and the evenness or steepness of the curve (e.g., the slope or gradient from most to least abundant genera; Agosti 2000). We used all sample data for assessment despite differences in sampling effort for the three collection methods and in the four ecoregions because the rank occurrence plot best represented the full assemblage of ant genera.

To compare the number of functional groups and genera captured in pitfall traps and at bait cards for each ecoregion, we divided the number of genera or functional groups captured in a sample by the total number of genera or functional groups captured in all samples, respectively. We compared these percentages within and between identification method and ecoregions. We made statistical comparisons using the PROC MIXED function in SAS 9.2 (SAS Institute Inc., Cary, NC, USA). We calculated pair-wise comparisons using the Tukey-Kramer method. We assessed similarity of the genera assemblages within and between the state's most distant ecoregions (i.e., High Plains and Western Corn Belt Plains) using Jaccard's Index (Magurran 1988, Agosti 2000). For standardization, we performed these calculations using ant data collected over three sample nights in each pitfall array; there were three pitfall arrays in each of the four locations used for this analysis. We sampled a north and south location in the Western Corn Belt Plains and an east and west location in the High Plains. We compared the similarity index values within and between ecoregion locations, and within and between microhabitat types to determine if ant genera similarity was more related to habitat type or location. The same process was used to compare the similarity of functional groups. A similarity index value of one means 100% similarity and zero means 0% similarity between the compared samples. The Jaccard's index values were clustered using the unweighted pair group method with arithmetic mean (UPGMA) to show the similarity between ecoregion sites for ant genera and functional groups.

RESULTS

We identified 7,873 ants comprising five subfamilies and 22 genera from 417 samples collected from 34 Nebraska counties (Fig. 1). We captured six functional groups (Table 1). The majority of collections were made in three ecoregions: Western Corn Belt Plains, Central Great Plains, and High Plains. We identified two ant genera in over 25% of the samples, *Formica* Linnaeus and *Lasius* Fabricius, both in the subfamily Formicinae (Table 1). We collected *Hypoponera* (Forel) (subfamily Ponerinae) in a single location using the pitfall trap method. We collected *Polyergus* Latreille (subfamily Formicinae), *Myrmecina* (subfamily Myrmicinae), and *Neivamyrmex* Borgmeier (subfamily Ecitoninae) in three or fewer locations. The rarity of these genera and the commonness of most other genera are illustrated in the rank occurrence plot (Fig. 2). Each individual ecoregion showed a steady decline or shallow slope in occurrence from the most abundant genera to the least abundant and did not have a marked decrease.

Table 1. Ant genera captured in 34 Nebraska counties (2004) with corresponding ecoregion occurrence and functional group identification.

	Number of occurrences							
	Card[a]	Direct[b]	Pitfall	CP[c]	Total	RO[d]	Ecoregion[e]	Group[f]
Aphaenogaster Mayr	47	10	6	1	64	7.21	CGP, HP, S, WCBP	O
Camponotus Mayr	28	26	1	0	55	6.19	CGP, HP, S, WCBP	O
Crematogaster Lund	42	20	2	1	65	7.32	CGP, HP, S, WCBP	G
Dorymyrmex Mayr	30	15	3	1	49	5.52	CGP, HP, S, WCBP	O
Forelius Emery	22	8	5	0	35	3.94	CGP, HP, S, WCBP	G
Formica (Fusca Group)	30	24	2	1	57	6.42	CGP, HP, S, WCBP	O
Formica (Microgyna Group)	0	1	0	0	1	0.11	CGP	O

Table 1. Continued.

	Number of occurrences							
	Card[a]	Direct[b]	Pitfall	CP[c]	Total	RO[d]	Ecoregion[e]	Group[f]
Formica (Neogagates Group)	17	20	1	1	39	4.39	CGP, HP, S, WCBP	O
Formica (Pallidefulva Group)	16	23	0	2	41	4.62	CGP, HP, S, WCBP	O
Formica (Rufa Group)	9	15	1	2	27	3.04	CGP, HP, S, WCBP	D
Formica (Sanguinea Group)	1	2	0	0	3	0.34	CGP, HP	SP
Hypoponera (Forel)	0	0	1	0	1	0.11	CGP	CS
Lasius (Niger Group)	59	33	11	2	105	11.82	CGP, HP, S, WCBP	G
*Lasius (*Claviger Group*)*	0	8	1	1	10	1.13	CGP, HP, WCBP	CS
Lasius (Flavus Group)	0	0	1	0	1	0.11	CGP	CS
Lasius (Umbratus Group)	0	2	0	1	3	0.34	CGP, HP, WCBP	O
Monomorium Mayr	16	3	3	0	22	2.48	CGP, HP, WCBP	G
Myrmecina Curtis	0	0	2	0	2	0.23	WCBP	O
Myrmica Latreille	46	16	11	4	77	8.67	CGP, HP, S, WCBP	O
Neivamyrmex Borgmeier	1	2	0	0	3	0.34	CGP, WCBP	SP
Nylanderia Emery	15	2	4	0	21	2.36	CGP, S, WCBP	O
Pheidole Westwood	25	13	8	1	47	5.29	CGP, HP, WCBP	G
Pogonomyrmex Mayr	6	14	1	1	22	2.48	CGP, HP	HCS
Polyergus Latreille	0	2	0	0	2	0.23	CGP, HP	SP
Prenolepis Mayr	2	4	1	0	7	0.79	CGP	G
Solenopsis Westwood	13	6	8	0	27	3.04	CGP, HP, S, WCBP	G
Stenamma Westwood	0	0	4	0	4	0.45	CGP, HP, WCBP	O
Tapinoma Foester	35	12	6	0	53	5.97	CGP, HP, S	O
Temnothorax Mayr	30	6	1	0	37	4.17	CGP, HP, WCBP	O
Tetramorium Mayr	5	3	0	0	8	0.9	HP	O
Total	495	290	84	19	888			

[a] Card = Bait Card; [b] Direct = Direct collection; [c] CP = Carrion pitfall; [d] RO = Relative occurrence; [e] CGP = Central Great Plains, HP = High Plains, S = Nebraska Sandhills, and WCBP = Western Corn Belt Plains; [f] Group = Functional group, O = Opportunists, G = Generalists, D = Dominants, SP = Specialist predators, CS = Cryptic species, HCS = Hot climate specialists.

The ant genera collected during our study represented 31% of the known genera within North America and represented 55% of the known genera in the Midwest (Table 2). The Central Great Plains ecoregion had the most genera and functional groups collected with 21 and 6, respectively. The Western Corn Belt Plains ecoregion was sampled the most intensively with 150 samples, but the High Plains ecoregion had the second highest number of genera recorded. No single ecoregion or collection method contained all of the identified genera. For both pitfall (Fig. 3a) and bait card (Fig. 3b) datasets, significantly higher percents of functional groups were collected than genera (pitfall: $F_{1,39} = 9.61$, $P = 0.004$ and bait card: $F_{1,\ 499} = 491.05$, $P \leq 0.001$). The Central Great Plains ecoregion had significantly higher percent captures than two other ecoregions (High Plains: $t_{39} = 4.33$, $P = 0.001$ and Western Corn Belt Plains: $t_{39} = 3.64$, $P = 0.004$) in pitfall traps and the Nebraska Sandhills ecoregion on bait cards ($t_{499} = 2.83$, $P = 0.02$).

Table 2. The number of ant subfamilies and genera found in Nebraska (2004), surrounding states[a], and North America[b].

Subfamily	North America	Surrounding states total	CO	IA	KS	NE	MO	SD	WY
Cerapachyinae	2	0	0	0	0	0	0	0	0
Dolichoderinae	11	6	4	3	4	4	5	4	4
Ecitoninae	3	1	1	1	1	1	1	0	0
Formicinae	9	8	7	7	8	7	7	7	6
Myrmicinae	34	20	15	12	13	13	14	11	12
Ponerinae	9	4	3	3	3	2	4	1	1
Proceratiinae	2	1	0	1	1	0	1	0	0
Total	70	40	30	27	30	26	32	22	23

[a] CO = Colorado, IA = Iowa, KS = Kansas, NE = Nebraska, MO = Missouri, SD = South Dakota, WY = Wyoming; [b] Sources as updated using Bolton et al. (2006): Bare 1929, Buren 1944, Gregg 1963, Schmitt 1973, Dubois 1985, Wheeler and Wheeler 1987, 1988, Dubois and Danoff-Burg 1994, Hedlund 2004, and Fisher and Cover 2007.

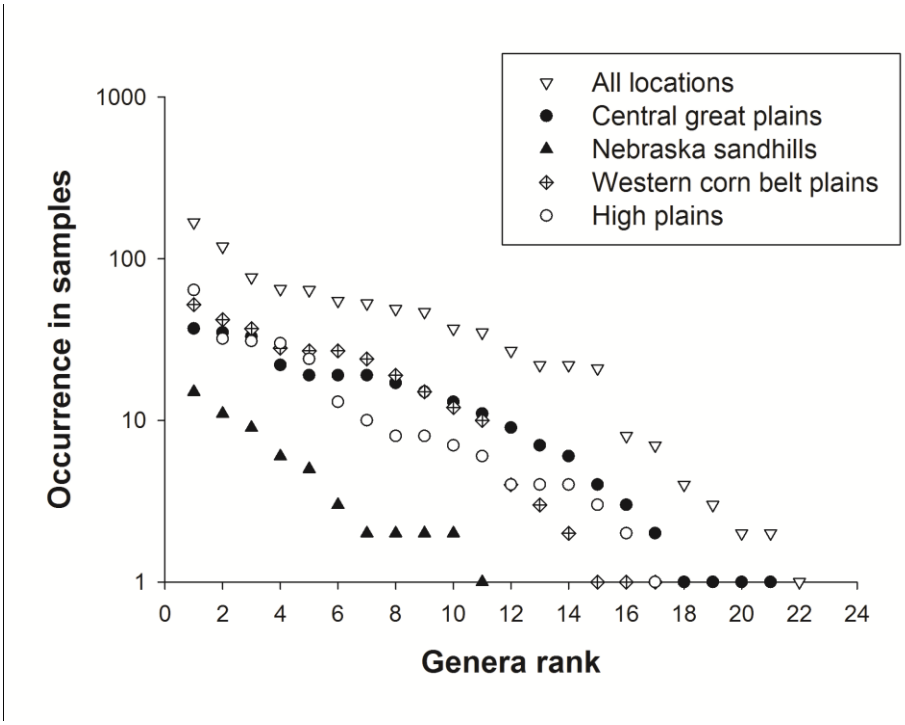

Figure 2. Ranked occurrence plot of ant genera sampled within Nebraska and four different level III ecoregions in 2004.

The similarity of ant genera samples collected within each ecoregion ranged from 0 to 60% and between ecoregion samples ranged from 0 to 38%. For both the ant genera and the ant functional group comparison the highest mean similarity index value was found within the Western Corn Belt Plains assemblages (Table 3). Only three functional groups were collected in the pitfall samples used for the genera and functional group similarity comparisons. One large cluster on the genera dendrogram showed a mix of all locations, but two other clusters show a majority of the Western Corn Belt Plains locations grouped and three of the High Plains locations grouped (Fig. 4a). The dendrogram for functional groups showed only one cluster with geographically closer locations grouped together (Fig. 4b). Similarity index values within and between microhabitats ranged from 0 to 60% for ant genera with mean similarity index values falling at or below 23% for all comparisons (Table 4). The microhabitat comparison using

ant functional groups showed higher similarity index values, but were variable between and within the different habitat designations (Table 4).

DISCUSSION

Our study provides a list of ant genera for four Level III ecoregions in Nebraska, which should prove to be useful for developing environmental assessment or monitoring tools. We were not able to effectively sample the Sandhills region, which is apparent in the occurrence plot (Fig. 2), and the steepness and short distance of the Nebraska Sandhills curve is likely an artifact of fewer samples and not a true indication of decreased ant genus richness and occurrence.

Our results support King and Porter's (2005) suggestion to use a structured inventory approach with multiple collection methods to more accurately assess the species richness and abundance of ants. Our three collection methods provided comparable coverage of genera despite unequal sampling efforts. In one sampling season (i.e., mid-May to mid-August) and with only three to four days in each general location, we identified 22 genera, which is comparable to the numbers of ant genera found in surrounding states. The richness and prevalence of ants caught by pitfall traps may be explained by temporal niche partitioning of ants, which was not accounted for in either direct or bait card collections (Albrecht and Gotelli 2001). Collection of cryptic, tiny, or rarely encountered genera, such as *Lasius* (Claviger group), *Myrmecina*, *Polyergus*, and *Solenopsis* Westwood, was made using all three sampling techniques confirming that a variety of collection methods are needed. The use of litter sampling methods, such as the Winkler extraction method, would have increased the likelihood of capturing litter or subterranean ants compared to our methods, which focused on above-ground foraging ant species (Agosti 2000, Gotelli et al. 2011).

Table 3. Mean Jaccard's index values for ant genera and ant functional groups found in pitfall samples located in 12 locations within two different Nebraska ecoregions.

Genera	Jaccard's similarity index values	
High Plains	0.22	
Western Corn Belt Plains	0.14	0.33
	High Plains	Western Corn Belt Plains
Functional group	**Jaccard's similarity index values**	
High Plains	0.53	
Western Corn Belt Plains	0.52	0.64
	High Plains	Western Corn Belt Plains

Table 4. Mean Jaccard's index values for ant genera and ant functional groups found in pitfall samples located in twelve locations within four different microhabitats.

Genera	Jaccard's similarity index values			
Grass	0.17			
Mixed	0.23	0.40		
Sand	0.22	0.15	0.00	
Woody	0.17	0.34	0.12	0.00
	Grass	Mixed	Sand	Woody
Functional group	**Jaccard's similarity index values**			
Grass	0.57			
Mixed	0.54	0.33		
Sand	0.58	0.38	0.50	
Woody	0.58	0.38	0.75	0.50
	Grass	Mixed	Sand	Woody

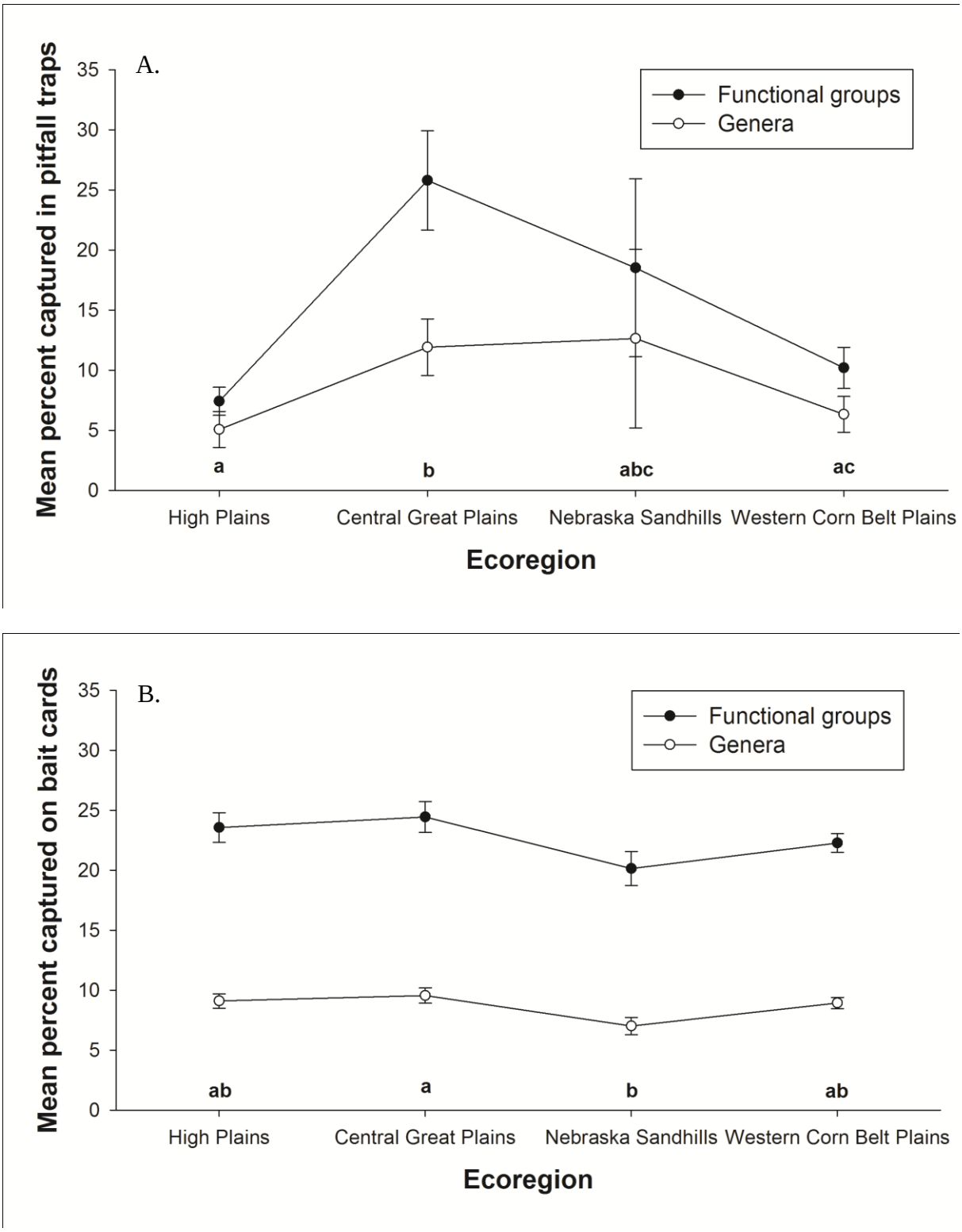

Figure 3. Mean percent of functional groups and genera captured in pitfall traps (A) and on bait cards (B) for each of the four sampled ecoregions. Letters indicate significance ($\alpha = 0.05$) between ecoregions.

Previous studies show that there is a general trend of decreasing ant diversity with increasing latitude (Kusnezov 1957, Folgarait 1998). Because Nebraska's latitudinal location is between Kansas and South Dakota, the number of genera found in Nebraska would be expected to be intermediate, which was confirmed by our sampling (Table 2). Two of the North American subfamilies, Cerapachyinae and Proceratiinae, were not found in this study, but only Proceratiinae has been found in surrounding states. In addition to the 22 genera identified in this study, Bare (1929) listed the presence of *Brachymyrmex* Mayr and *Ponera* Latreille in Nebraska, and Schmitt (1973) listed *Dolichoderus* Lund and *Harpagoxenus* Forel in Pierce County, Nebraska. These additions make the total known ant genera found in Nebraska to 26 genera or 68% of the peer-reviewed, published genera in the Midwest.

Although several introduced ant species occur in surrounding states, only *Tetramorium caespitum* Wang is known to be in this dataset. Some genera, such as *Polyergus* and *Neivamyrmex*, were easily identifiable compared to other ant genera in Nebraska because of their distinct morphological features. These genera would be of interest for further research because of their unique life histories. The *Polyergus* genus is a group of slave-making ants, which are tightly associated with *Formica* colonies and *Neivamyrmex* are a subterranean, temperate group of army ants, which move their nests, called bivouacs, frequently (Fisher and Cover 2007).

The mean percent ant genera and functional groups collected showed similar trends when compared by both ecoregion and sampling method (Figs. 3a and 3b). These data indicate that the same sampling methods can adequately represent either the genus or functional group. Use of ant genera as a higher taxon surrogate for ant species richness was found to be a good indicator in a study conducted across a Himalayan region of India (Negi and Gadgil 2002), but its use was only partially supported in a cross-continental analysis (Rosser and Eggleton 2011). A greater similarity within ecoregions than between ecoregions was indicated by the mean similarity index values (Table 3), which does not appear to be related to differences in microhabitat (Tables 4). We did not find a difference in similarity index value trends between the general locations within ecoregions (Fig. 4a and 4b) and may, in part, be explained by our focus on public lands managed for wildlife which were similar within ecoregions or because the use of ant genera or functional group did not have enough taxonomic resolution. Jaccard's similarity index values should be cautiously interpreted because although they show similarity based on genera, the individual species may be different between the two assemblages being compared.

Overall, our data suggest that the functional group designations were as helpful or less helpful in detecting habitat differences across the state based on the ability to capture an average 25% of the possible functional groups with pitfall and bait card collections methods and the resulting similarity index values. The similarity values for functional groups were limited to four possible results because only three groups were found in the dataset; however, the general pattern produced may not have been affected.

Underwood and Fisher (2006) reviewed the role of ants in conservation and found several functional uses of ant surveys: 1) measuring impacts by invasive species, 2) recognition of trends among threatened, endangered or keystone species, and 3) evaluation and assessment of land management actions or ecosystem changes over time. The use of ant survey information at the genus level, rather than species-level or comprehensive invertebrate surveys, to characterize habitat differences has important implications at a reduced cost and increased efficiency in assessment protocols (Underwood and Fisher 2006). Because the conservation of community types and biodiversity is important to the overall health of our natural ecosystems (Humphries et al. 1995; Sieg et al. 1999), future work characterizing ant associations with rare habitats is needed to aid in the conservation of unique ecosystems in Nebraska. Although the presentation of genus numbers by state, or even county, is an artificial separation, it provides a starting point to assess general trends for regional monitoring. A complete species checklist of this dataset with county information is in progress. We hope that our list of ant genera by ecoregion will also be useful to researchers or habitat managers and that similar comparative studies will be developed for the central U.S.

MANAGEMENT IMPLICATIONS

By using sampling techniques that were relatively simple and cost effective, our findings indicated that ant genus diversity of Nebraska is comparable to other states, ants are relatively easy to identify to genus, and ant genera identification can provide enough taxonomic information to distinguish between large-scale habitat differences. Functional group identification may be useful, but it is less taxonomically sufficient because of the increased effort needed to identify specimens beyond genus. We recommend that pitfall sampling be modified to a single collection of the pitfall trap samples after 72 hours rather than repeated collection every 24 hours. The use of non-toxic anti-freeze mixed with water would help prevent the decay of samples. The sampling effort using bait cards should also be standardized for each sampling location and manual collection of specimens should be structured by search time (e.g., five minutes per microhabitat), along with a standardized number of searches per location. Creation of microhabitat designations beforehand to assist in characterizing each location's habitat types could also be the basis of a standardized number of samples for each location.

Additional ant inventories should target the two unsampled ecoregions and one minimally sampled ecoregion in Nebraska. This is useful information to the biological community in Nebraska and the Great Plains because it provides another tool for the conservation and monitoring of habitats.

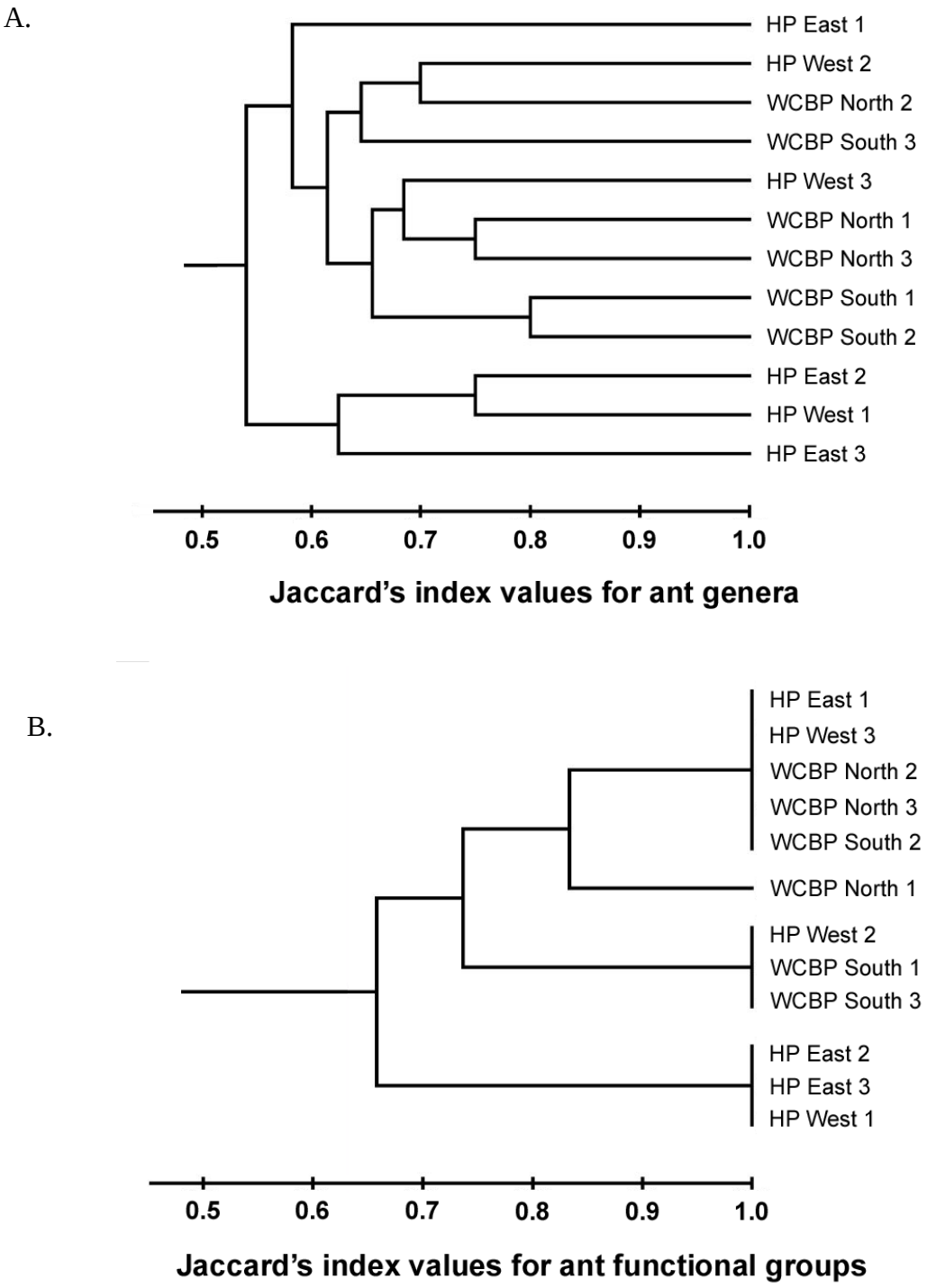

Figure 4. Dendrogram illustrating Jaccard's index values for each pitfall sample by genera (A) and functional group (B). Nodes at larger index values indicate a higher similarity. HP and WCBP stands for High Plains and Western Corn Belt Plains, respectively.

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